BULK DENSITY ESTIMATION BY GAMMA-RAY ATTENUATION DENSIOMETRY

Introduction

Bulk density is a measure of mass per unit volume, typically expressed as grams per cubic centimeter (g/cm^3). In the earth sciences, bulk density is often an indicator of changes in lithology (mineral composition, grain size and other physical characteristics) and porosity (the spaces between mineral grains that can be filled with gas or fluid). The correlation of bulk density and porosity to other properties of rocks and sediments led to the development of the GRAPE (Gamma-Ray Attenuation Porosity Evaluator) by Marathon Oil Company during the 1960s (Boyce, 1973). The principle is based on the facts that medium-energy gamma rays interact with rock or sediment mainly by Compton scattering. The mass attenuation coefficients for most rock-forming elements are similar, so the attenuation of gamma rays can be directly related to the density of the material.

The Ocean Drilling Program (ODP) started where the Deep Sea Drilling Project (DSDP) left off. Much of the scientific expertise and laboratory equipment were transferred from the DSDP, including the GRAPE system. This allowed the scientists sailing on the first cruise of ODP to continue collecting this type of data which had been measured since early in the DSDP. The bulk density dataset as measured by the GRA systems provides a very large, densely sampled record of bulk density for over 80% of the 222 km of core collected throughout the world by the ODP.

GRA Data Acquisition

The ODP started operations with the DSDP GRAPE hardware and software. Basically, the GRAPE system consisted of a drive device that moved a section of core between a shielded gamma-ray source (^{133}Ba) and a shielded scintillation detector. Modifications and upgrades were made as improvements in computers and data acquisition technology became available, and scientific objectives changed. The system eventually was referred to as the GRA densiometer because the device measurements were used to calculate density not porosity. An automated core conveying and positioning system called MST (MultiSensor Track) was installed during Leg 124E with an upgraded GRA system. This new GRA system finally retired the last of the GRAPE components as a new source (^{137}Cs) and NaI scintillation detectors were installed.

The table below briefly outlines the modification history of the systems that have been used to collect the bulk density data. The acronym GRAPE will be used when referring to measurements taken with the original ^{133}Ba source and detectors of the DSDP GRAPE system. Likewise, GRA will be used when referring to the ODP system with the ^{137}Cs and NaI scintillation detectors or when referring to the bulk density dataset as a whole. More detailed descriptions of both DSDP and ODP bulk density measurements can be found in Boyce (1973, 1976) and Blum (1997).

Table 1. GRA Densiometer systems.

Legs	Equipment	Comments
101 - 115 (Site 713)	DSDP GRAPE - ^{133}Ba source	Leg 108 – PWL (P-Wave Logger) mounted on GRAPE sample track. Leg 113 - data acquisition software installed on DEC Pro350
115 (Site 714) – 124	Vertical GRAPE	GRAPE source and detectors mounted on a vertical track.
124E	MST – GRA ^{137}Cs source - 660 KeV gamma rays, standard NaI scintillation detector	Initial installation of MST with GRA, PWL and MSL. Not all software compatible with shipboard environment, but system operational.
125 - 133	MST Track - GRA	Minor software changes during this time.
133 (Site 818) – 150	MST Track - GRA	Leg 133 - Major software upgrade. Boyce-corrected density calculated and written into the data files; Leg 149 – NGR added to track.
151 – 162	MST Track - GRA	Leg 151 – Major software upgrade.
163 – 169 (Site 1036)	MST Track – GRA	Major software upgrade installed Leg 163 Port Call.
169 (Site 1037) – 187	MST Track – GRA	Hardware and software upgrade. Fluid density correction made within program due to new calibration procedure. Leg 171 Janus database operational.
188 – 210	MST Track – GRA	Minor software changes during this time.

Standard Operating Procedures

At the beginning of the ODP, the Shipboard Scientist’s Handbook (1987) instructed that the sections could be run through the GRAPE analyses while they stabilized for thermal conductivity measurements. After additional sensors whose measurements were temperature sensitive were added to the track, cores were stored on a rack to allow them to equilibrate to room temperature before analysis. The highest quality of GRA data were made on core liners that were completely full. It was recommended that only APC (hydraulic piston coring, H core type) cores be analyzed because APC coring routinely recovered soft sediment that filled the core liner. XCB (Extended Core Barrel) and RCB (Rotary Core Barrel) cores were often disturbed, containing biscuits of core surrounded by drilling mud or irregular pieces of core, and did not completely fill the core liner. With the older DSDP track, it would often take up to 2 hours to make GRAPE measurements on one core. Considering the amount of time to make these measurements and the poorer quality of data, hard rock cores and disturbed cores were not usually run in continuous mode. These cores were sometimes analyzed by GRAPE-2, a longer-count density measurement taken on samples or discrete locations on a section.

Calibration

There have been two different calibration procedures used during the ODP. Aluminum was the material chosen for the calibration standard because aluminum has an attenuation coefficient similar to common minerals. The calibration standard used until Leg 168 consisted of two aluminum cylinders of different thickness mounted in a liner. The thicker rod was designed to give a density of 2.7 g/cm^3 and the thinner rod was to give a density of 1.00. But with this procedure, the density of water was overestimated by about 11% (Boyce, 1973). A fluid correction was applied to the bulk density estimate to compensate for the overestimation of water density.

The data collection and calibration procedures set up and described by Robert Boyce (1973, 1976) were used throughout the first part of ODP even though modifications had been made to the system. The installation of the MST and new GRA system marked a major change to both hardware and software. Documentation of calibration procedures, frequency of calibration and the calibration parameters used for the density calculations were difficult if not impossible to find before Leg 124 when the MST was installed with a major software upgrade. After that system was installed, files were created that contained the analysis of the standard; however, these files were not always saved, and the calibration history was not documented. The software upgrade during Leg 163 resulted in a major change in the data file format. The calibration date and parameters were written in the header of the data file. From this point, the calibration history of GRA data was documented.

A new calibration procedure was implemented during Leg 169. This new procedure incorporated a two-phase standard - a telescoping aluminum rod (five elements of varying thickness) and pure water. Because of the two-phase standard, the fluid correction was no longer necessary because water was used in the calibration procedure. For a full discussion of the calibration procedures see Blum (1997).

Table 2. Calibration procedures

Legs	Calibration Standard	Calibration Procedure
101 – 164	80 cm in-liner tapered Aluminum rod	Run aluminum rod until density values of 2.7 and 1.0 were measured.
164 – 169 (Site 1036)	80 cm in-liner tapered Aluminum rod	Calibration file created.
169 (Site 1037) – 210	Telescoping aluminum rod in liner, diameter from 6.6 cm to 0 and filled with distilled water	Two-phase standard incorporates correct water density into calibration parameters.

Archive

Pre-Janus Archive

Most of the original GRAPE and GRA data files were archived on the ODP/TAMU servers. There was no interim database for GRA data. In a few instances, the files for a hole were concatenated into a single file. Some of these original files are no longer available, either because the scientists who concatenated the hole file deleted them, or they were not moved onto the ODP/TAMU servers.

Migration of GRA Bulk Density to Janus

The data model for GRA Bulk Density can be found in Appendix I. Included are the relational diagram and the list of the tables that contain data pertinent to GRA, the column names, and the definition of each column attribute. ODP Information Services Database Group was responsible for the migration of pre-Leg 171 data to Janus. The migration of GRA bulk density was done in conjunction with the other MST datasets – Magnetic Susceptibility Logger, P-Wave Logger and Natural Gamma Radiation. Each change in format was documented and added to the MST Migration program. Additional information about the migration of GRA data or original file formats can be requested from the IODP Data Librarian.

As noted in the calibration section above, the raw bulk density value overestimated the density of water. The raw data files created before Leg 133 contained the uncorrected bulk density. After Leg 133, the Boyce Density Correction was applied to the density value and written in the data files. During the migration of GRA data to Janus, the Boyce Density Correction was applied to all the bulk density values that had not already been recalculated, Legs 101 – 133, Site 818. The fluid correction calculation is:

Boyce Corrected Density = (Density – 1.128) * 1.626 / 1.522) + 1.024.

Janus GRA Data Format

The GRA data can be retrieved from Janus Web using a predefined query. The GRA Bulk Density query webpage allows the user to extract data using the following variables to restrict the amount of data retrieved: leg, site, hole, core, section, specific run numbers, range in density values, depth ranges, or latitude and longitude range. In addition, the user can use the Output Raw Data option in the query to extract the raw measurements and calibration parameters used to calculate the bulk density values. Because there are over 9.2 million GRA data records in Janus, a user must restrict the amount of data requested.

Table 3 lists the data fields retrieved from the Janus database for the predefined GRA query with Output Raw Data option turned on. The first column contains the data item; the second column indicates the Janus table or tables in which the data were stored; the third column is the Janus column name or the calculation used to produce the value.

Appendix II contains additional information about the fields retrieved using the Janus Web GRA query, and the data format for the archived ASCII files.

Table 3. GRA Bulk Density query with Output Raw Data option

Item Name	Janus Table	Janus Column Name and Calculation
Leg	SECTION	Leg
Site	SECTION	Site
Hole	SECTION	Hole
Core	SECTION	Core
Type	SECTION	Core_type
Section	SECTION	Section_number
Top (cm)	GRA_SECTION_DATA	MST_Top_Interval x 100
Depth (mbsf)	DEPTH_MAP, GRA_SECTION_DATA	DEPTH_MAP.Map_Interval_Top + GRA_SECTION_DATA.MST_Top_Interval
Density (g/cc)	GRA_SECTION_DATA	**Legs 169 Site 1037 -- 210:** DENSITY = GRA_CALIBRATION.density_M0 + GRA_CALIBRATION.density_M1 * ln (GRA_SECTION_DATA.meas_counts / GRA_SECTION_DATA.actual_daq_period) **Legs 101-169, Site 1036:** GRA_SECTION_DATA.boyce_corrected_density = ((DENSITY - 1.128) * 1.626 / 1.522) + 1.024.
Run Number	GRA_SECTION	Run_Number
Run Date/Time	GRA_SECTION	Run_Date_Time (yyyy-mm-dd hh:mm)
Core Status	GRA_SECTION	Core_Status
Liner Status	GRA_SECTION	Liner_Status
Requested Interval	GRA_SECTION	Requested_DAQ_Interval (Legs 101 - 162 interval units in seconds; Legs 163 - 210 interval units in centimeters)
Requested Period (s)	GRA_SECTION	Requested_DAQ_Period
Actual Period (s)	GRA_SECTION_DATA	Actual_DAQ_Period
Counts per Second	GRA_SECTION_DATA	Meas_Counts
Core Diameter (cm)	GRA_SECTION_DATA	Core_Diameter
Calib. Date/Time	GRA_CALIBRATION	Calibration_Date_Time (yyyy-mm-dd hh:mm)
Calib. Intercept (g/cc)	GRA_CALIBRATION	Density_M0
Calib. Slope (g/cc)	GRA_CALIBRATION	Density_M1

Data Quality

There are several things that can affect the quality of GRA data. Type of cored material and the drilling method used to recover the core are major factors. Hydraulic piston coring (APC, coretype H) used to recover softer, undisturbed sediments will routinely give the best results because the core liner is usually full. However, the sediments can also contain a lot of gas which will create voids in the cored material. Cores cut by XCB and RCB are often biscuits surrounded by drilling mud or irregularly-shaped pieces. Voids, smaller diameter core, irregular pieces, thin runny mud will all give GRA density values that are low. Table 4 summarizes how much of the different types of core were analyzed on the GRA systems.

Table 4: GRA Analysis Statistics

	Core Recovery	**GRA Analyzed**	**Percent**
APC – coretype H	113,999 meters	103,518 meters	90.8 %
XCB – coretype X	61,638 meters	51,054 meters	82.8 %
RCB – coretype R	45,869 meters	29,755 meters	64.9 %
TOTAL	222,429 meters	184,476 meters	82.9 %

Even though the Shipboard Scientist's Handbook specified that GRA measurements should only be made on APC cores, the addition of other sensors to the GRAPE track and eventually the MST made it more of a temptation to run less than ideal cores through the GRA system. This did not mean that GRA density analyses on XCB and RCB cores have become more accurate. GRA values on anything but APC cores should be used with some skepticism. For more information on GRA bulk density measurements, see the chapter on Gamma-Ray Densiometry from the Physical Properties Handbook (Blum, 1997).

There are a couple of mechanical factors that affect the quality of GRA density measurements. The GRA systems have always been installed on a track which either moved the section past the source and detectors, or moved the source and detectors along the vertical section. Sample measurements were a function of the speed of the track and sampling time. Slight variation of track speed may account for the irregular spacing of data points.

The core sections were run through the GRA system before the liners were opened and the core curated. During the curation process, core material was often shifted. In sedimentary cores, voids may have been closed. Gassy cores may have small voids that continue to enlarge after analysis. Sections may not be completely full, and material may have spread throughout the liner. After curation, this material was shoved up to close voids and the section's curated length was less than what was originally analyzed. The effects can be seen when looking at the data for a section: 1) there are reasonable density values beyond the curated length of the section (null depth values); 2) there are negative density values within the section indicating a measurement in a void or less than full liner.

Hard rock cores can be continuous cylinders with uniform diameter or can be broken into small irregular pieces. The curation process shifts hard rock pieces, sometimes even shifting core material from its original liner section to an adjacent section liner. Where the core material was in its liner during analysis and where it was eventually placed after curation can be very different. GRA data for these types of cores should be used with caution.

Operator error may also be a source of errors. Throughout the ODP, the operator manually entered core information into the data acquisition program. Typographical errors or entering wrong information occasionally happened, and some mistakes were not identified. Sometimes, the scientific party noticed the error and corrected it for the data included in the Initial Report volume, but the original files did not get corrected. A lot of effort during verification of the migrated GRA data has gone into finding sections that may have been misidentified. Some runs have been renamed to different sections. The evidence for misidentification had to be conclusive. Listed below are some of the clues used to find incorrectly identified analyses:

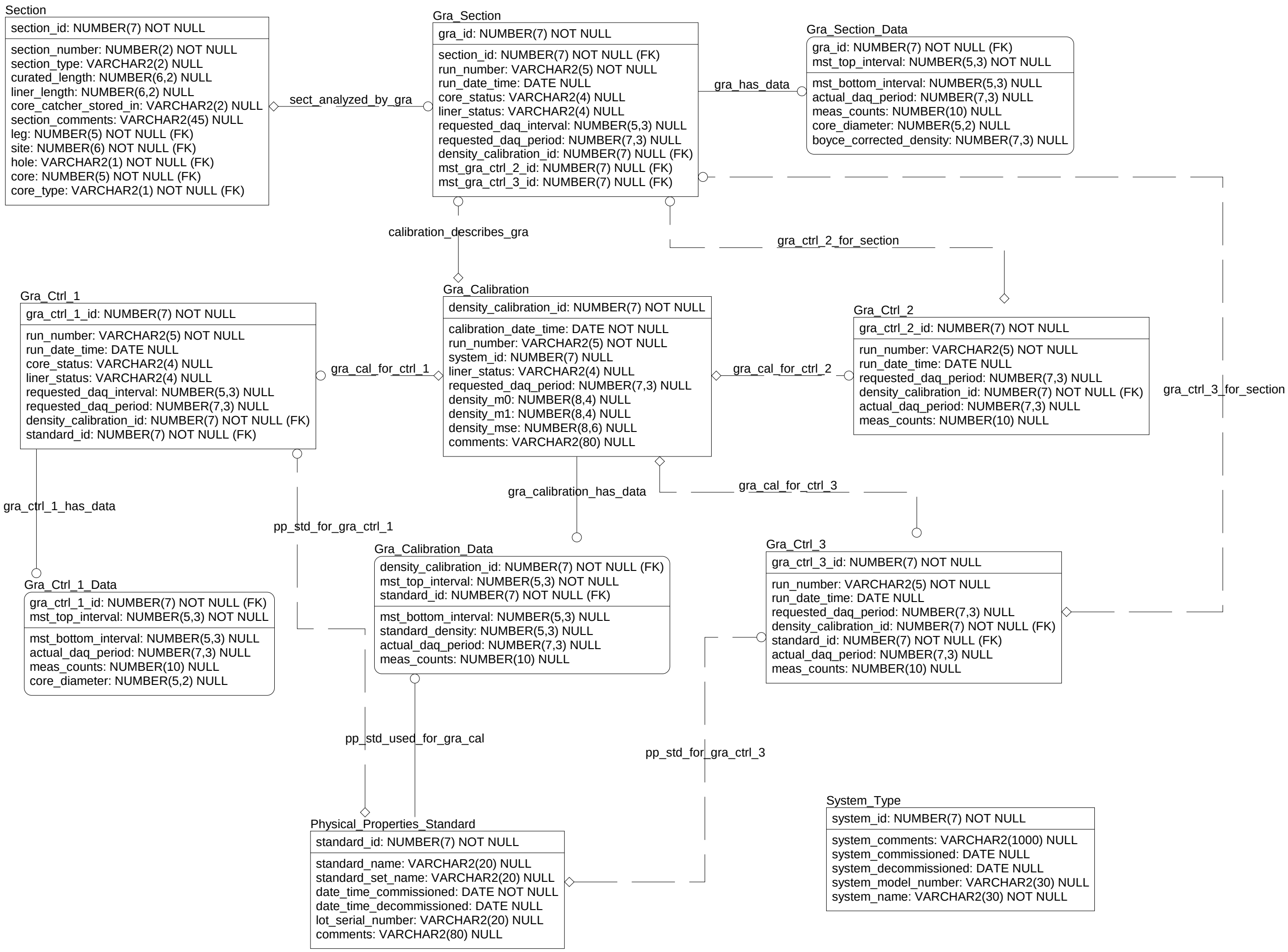
- two runs for a section, no run for the following section;
- run numbers out of sequence;
- two runs for a section, run numbers out of sequence - no data for that core and section in a different hole, but sequence of run numbers would be correct.
- Nature of the core material – length of core, voids or less than full liners

References

Blum, P., 1997, Physical Properties Handbook: A guide to the shipboard measurement of physical properties of deep-sea cores, ODP Tech. Note 26.

Boyce, R.E., 1973, Appendix I. Physical Properties - Methods. *In* Edgar, N.T., Saunders, J.B., et al., Initial Reports of the Deep Sea Drilling Project, Volume 15: Washington (U.S. Government Printing Office), p. 1115-1128.

Boyce, R.E., 1976, Appendix I. Definitions and Laboratory Techniques of Compressional Sound Velocity Parameters and Wet-Water Content, Wet-Bulk Density, and Porosity Parameters by Gravimetric and Gamma Ray Attenuation Techniques. *In* Schlanger, S.O., Jackson, E.D., et al., Initial Reports of the Deep Sea Drilling Project, Volume 33, p. 931-951.


Section
section_id: NUMBER(7) NOT NULL
section_number: NUMBER(2) NOT NULL
section_type: VARCHAR2(2) NULL
curated_length: NUMBER(6,2) NULL
liner_length: NUMBER(6,2) NULL
core_catcher_stored_in: VARCHAR2(2) NULL
section_comments: VARCHAR2(45) NULL
leg: NUMBER(5) NOT NULL (FK)
site: NUMBER(6) NOT NULL (FK)
hole: VARCHAR2(1) NOT NULL (FK)
core: NUMBER(5) NOT NULL (FK)
core_type: VARCHAR2(1) NOT NULL (FK)
sect_analyzed_by_gra
Gra_Section
gra_id: NUMBER(7) NOT NULL
section_id: NUMBER(7) NOT NULL (FK)
run_number: VARCHAR2(5) NOT NULL
run_date_time: DATE NULL
core_status: VARCHAR2(4) NULL
liner_status: VARCHAR2(4) NULL
requested_daq_interval: NUMBER(5,3) NULL
requested_daq_period: NUMBER(7,3) NULL
density_calibration_id: NUMBER(7) NULL (FK)
mst_gra_ctrl_2_id: NUMBER(7) NULL (FK)
mst_gra_ctrl_3_id: NUMBER(7) NULL (FK)
gra_has_data
Gra_Section_Data
gra_id: NUMBER(7) NOT NULL (FK)
mst_top_interval: NUMBER(5,3) NOT NULL
mst_bottom_interval: NUMBER(5,3) NULL
actual_daq_period: NUMBER(7,3) NULL
meas_counts: NUMBER(10) NULL
core_diameter: NUMBER(5,2) NULL
boyce_corrected_density: NUMBER(7,3) NULL
calibration_describes_gra
gra_ctrl_2_for_section
Gra_Ctrl_1
gra_ctrl_1_id: NUMBER(7) NOT NULL
run_number: VARCHAR2(5) NOT NULL
run_date_time: DATE NULL
core_status: VARCHAR2(4) NULL
liner_status: VARCHAR2(4) NULL
requested_daq_interval: NUMBER(5,3) NULL
requested_daq_period: NUMBER(7,3) NULL
density_calibration_id: NUMBER(7) NOT NULL (FK)
standard_id: NUMBER(7) NOT NULL (FK)
gra_cal_for_ctrl_1
Gra_Calibration
density_calibration_id: NUMBER(7) NOT NULL
calibration_date_time: DATE NOT NULL
run_number: VARCHAR2(5) NOT NULL
system_id: NUMBER(7) NULL
liner_status: VARCHAR2(4) NULL
requested_daq_period: NUMBER(7,3) NULL
density_m0: NUMBER(8,4) NULL
density_m1: NUMBER(8,4) NULL
density_mse: NUMBER(8,6) NULL
comments: VARCHAR2(80) NULL
gra_cal_for_ctrl_2
Gra_Ctrl_2
gra_ctrl_2_id: NUMBER(7) NOT NULL
run_number: VARCHAR2(5) NOT NULL
run_date_time: DATE NULL
requested_daq_period: NUMBER(7,3) NULL
density_calibration_id: NUMBER(7) NOT NULL (FK)
actual_daq_period: NUMBER(7,3) NULL
meas_counts: NUMBER(10) NULL
gra_ctrl_3_for_section
gra_ctrl_1_has_data
gra_calibration_has_data
gra_cal_for_ctrl_3
pp_std_for_gra_ctrl_1
Gra_Calibration_Data
density_calibration_id: NUMBER(7) NOT NULL (FK)
mst_top_interval: NUMBER(5,3) NOT NULL
standard_id: NUMBER(7) NOT NULL (FK)
mst_bottom_interval: NUMBER(5,3) NULL
standard_density: NUMBER(5,3) NULL
actual_daq_period: NUMBER(7,3) NULL
meas_counts: NUMBER(10) NULL
Gra_Ctrl_3
gra_ctrl_3_id: NUMBER(7) NOT NULL
run_number: VARCHAR2(5) NOT NULL
run_date_time: DATE NULL
requested_daq_period: NUMBER(7,3) NULL
density_calibration_id: NUMBER(7) NOT NULL (FK)
standard_id: NUMBER(7) NOT NULL (FK)
actual_daq_period: NUMBER(7,3) NULL
meas_counts: NUMBER(10) NULL
Gra_Ctrl_1_Data
gra_ctrl_1_id: NUMBER(7) NOT NULL (FK)
mst_top_interval: NUMBER(5,3) NOT NULL
mst_bottom_interval: NUMBER(5,3) NULL
actual_daq_period: NUMBER(7,3) NULL
meas_counts: NUMBER(10) NULL
core_diameter: NUMBER(5,2) NULL
pp_std_used_for_gra_cal
pp_std_for_gra_ctrl_3
System_Type
system_id: NUMBER(7) NOT NULL
system_comments: VARCHAR2(1000) NULL
system_commissioned: DATE NULL
system_decommissioned: DATE NULL
system_model_number: VARCHAR2(30) NULL
system_name: VARCHAR2(30) NOT NULL
Physical_Properties_Standard
standard_id: NUMBER(7) NOT NULL
standard_name: VARCHAR2(20) NULL
standard_set_name: VARCHAR2(20) NULL
date_time_commissioned: DATE NOT NULL
date_time_decommissioned: DATE NULL
lot_serial_number: VARCHAR2(20) NULL
comments: VARCHAR2(80) NULL

APPENDIX I: Janus Data Model – GRA Densiometer

Gamma-Ray Densiometer - GRA		
Table Name	**Column Name**	**Column Comment**
Gra_Section	gra_id	Unique Oracle-generated sequence number for each GRA analysis run.
	section_id	Unique Oracle-generated sequence number to identify each section.
	run_number	Number identifying a run generated by the data acquisition software. This number is not used to identify the run in Janus because it may not be unique.
	run_date_time	Timestamp when analysis was run.
	core_status	Indicates if a full or half (split) core is being analyzed. Valid values are FULL or HALF.
	liner_status	Records if a core liner was used, a split liner or no liner. Valid values are FULL, HALF and NONE.
	requested_daq_interval	The data acquisition interval requested for section analysis, in cm.
	requested_daq_period	The data acquisition period requested, in seconds.
	density_calibration_id	Unique Oracle generated sequence number for each density calibration recorded for the GRA instrument.
	mst_gra_ctrl_2_id	Unique Oracle-generated sequence identifier for GRA control-2 runs.
	mst_gra_ctrl_3_id	Unique Oracle-generated sequence identifier for GRA control-3 runs.

Gra_Section_Data	gra_id	Unique Oracle-generated sequence number for each GRA analysis run.
	mst_top_interval	The top interval of a measurement in meters measured from the top of a section.
	mst_bottom_interval	The bottom interval of a measurement in meters measured from the top of a section.
	actual_daq_period	The actual data acquisition period used for measurements, in seconds.
	meas_counts	The actual raw measured counts collected by a GRA instrument during a measurement.
	core_diameter	Diameter of core, in cm.
	boyce_corrected_density	Estimated bulk density value with fluid correction factor applied. Applies to bulk density data collected before Leg 169, Site 1037.

Gra_Calibration	density_calibration_id	Unique Oracle-generated sequence number for each density calibration recorded for the GRA instrument.
	calibration_date_time	Timestamp when calibration was run.
	run_number	Number identifying a run generated by the data acquisition software. This number is not used to identify the run in Janus because it may not be unique.
	system_id	Unique identifier for a system of equipment on the ship.
	liner_status	Records if a core liner was used, a split liner or no liner. Valid values are FULL, HALF and NONE.
	requested_daq_period	The data acquisition period requested in seconds.
	density_m0	The intercept (m0) determined for a GRA calibration, in g/cm^3.
	density_m1	The slope (m1) determined for a GRA calibration, in (g/cm^3)/counts.
	density_mse	The mean-squared error determined for a GRA calibration.
	Comments	General comments.

Gra_Calibration_ Data	density_calibration_id	Unique Oracle-generated sequence number for each density calibration recorded for the GRA instrument.
	mst_top_interval	The top interval of a measurement in meters measured from the top of a standard.
	standard_id	Unique identifier for a physical properties standard.
	mst_bottom_interval	The bottom interval of a measurement in meters measured from the top of a standard.
	standard_density	Density of the standard, in g/cm^3.
	actual_daq_period	The actual data acquisition period used for measurements, in seconds.
	meas_counts	Raw measured counts collected by a GRA instrument during a calibration measurement.

Gra_Ctrl_1	gra_ctrl_1_id	Unique Oracle-generated sequence identifier for GRA control-1 runs, used to compare a sample run to a control-1 run.
	run_number	Number identifying a run generated by the data acquisition software. This number is not used to identify the run in Janus because it may not be unique.
	run_date_time	Timestamp when analysis was run.

Gamma-Ray Densiometer - GRA

Table Name	Column Name	Column Comment
	core_status	Indicates whether a whole or half (split) core is being analyzed. Valid values are FULL or HALF.
	liner_status	Records if a core liner was used, a split liner or no liner. Valid values are FULL, HALF and NONE.
	requested_daq_interval	The data acquisition interval requested for section analysis, in cm.
	requested_daq_period	The data acquisition period requested, in seconds.
	density_calibration_id	Unique Oracle-generated sequence number for each density calibration recorded for the GRA instrument.
	standard_id	Unique identifier for a physical properties standard.

Gra_Ctrl_1_Data	gra_ctrl_1_id	Unique Oracle-generated sequence identifier for GRA control-1 runs, used to compare a sample run to a control-1 run.
	mst_top_interval	The top interval of a measurement in meters measured from the top of a section.
	mst_bottom_interval	The bottom interval of a measurement in meters measured from the top of a section.
	actual_daq_period	The actual data acquisition period used for measurements, in seconds.
	meas_counts	The actual raw measured counts collected by a GRA instrument during a measurement.
	core_diameter	Diameter of core, in cm.

Gra_Ctrl_2	gra_ctrl_2_id	Unique Oracle-generated sequence identifier for GRA control-2 runs, used to associate a sample run to a control-2 run.
	run_number	Number identifying a run generated by the data acquisition software. This number is not used to identify the run in Janus because it may not be unique.
	run_date_time	Timestamp when analysis was run.
	requested_daq_period	The data acquisition period requested in seconds.
	density_calibration_id	Unique Oracle-generated sequence number for each density calibration recorded for the GRA instrument.
	actual_daq_period	The actual data acquisition period used for measurements, in seconds
	meas_counts	The actual raw measured counts collected by a GRA instrument during a measurement.

Gra_Ctrl_3	gra_ctrl_3_id	Unique Oracle-generated sequence identifier for GRA control-3 runs, used to associate a sample run to a control-3 run.
	run_number	Number identifying a run generated by the data acquisition software. This number is not used to identify the run in Janus because it may not be unique.
	run_date_time	Timestamp when analysis was run.
	requested_daq_period	The data acquisition period requested, in seconds.
	density_calibration_id	Unique Oracle-generated sequence number for each density calibration recorded for the GRA instrument.
	standard_id	Unique identifier for a physical properties standard.
	actual_daq_period	The actual data acquisition period used for measurements, in seconds.
	meas_counts	The actual raw measured counts collected by a GRA instrument during a measurement.

Physical_Properties_Standard	standard_id	Unique identifier for a physical properties standard.
	standard_name	Name of a physical properties standard.
	standard_set_name	The name for a set of physical properties standards.
	date_time_commissioned	The date that a physical properties standard went into use.
	date_time_decommissioned	The date that a physical properties standard's use discontinued.
	lot_serial_number	Information concerning the lot and/or serial number associated with a physical properties standard.
	comments	General comments

Section	section_id	Unique Oracle-generated sequence number to identify each section. This is done because of the physical subsection / zero section problems. In adding new sections, deleting sections or changing sections - don't want to have to renumber.
	leg	Number identifying the cruise for which data were entered into the database.
	site	Number identifying the site from which the core was retrieved. A site is the position of a beacon around which holes are drilled.

Gamma-Ray Densiometer - GRA		
Table Name	**Column Name**	**Column Comment**
	hole	Letter identifying the hole at a site from which a core was retrieved or data were collected.
	core	Sequential numbers identifying the cores retrieved from a particular hole. Cores are generally 9.5 meters in length, and are numbered serially from the top of the hole downward.
	core_type	A letter code identifying the drill bit/coring method used to retrieve the core.
	section_number	Cores are cut into 1.5 m sections. Sections are numbered serially, with Section 1 at the top of the core.
	section_type	Used to differentiate sections of core (S) from core catchers (C). Previously core catchers were stored as section CC, but in Janus core catchers are given the next sequential number from the last section recovered.
	curated_length	The length of the section core material, in meters. This may be different than the liner length for the same section. Hard rock cores will often have spacers added to prevent rock pieces from damaging each other.
	liner_length	The original length of core material in the section, in meters. Sum of liner lengths of all the sections of a core equals core recovery.
	core_catcher_stored_in	Sometimes the core catcher is stored in a D tube with a section. core_catcher_stored_in contains the section number of the D tube that holds the core catcher.
	section_comments	Comments about this section

System_Type	system_id	Unique identifier for a system of equipment used to collect data.
	system_comments	Comments associated with a piece of analytical equipment
	system_commissioned	Date that a piece of equipment was deployed to collect scientific data for the ODP.
	system_decommissioned	Date that a piece of analytical equipment was no longer used by the ODP.
	system_model_number	The model number of a piece of equipment used for scientific analysis.
	system_name	The name for a piece of equipment used for analysis.

Appendix II: Description of data items from GRA query.

Column Name	Column Description and Calculation	Format
Leg	Number identifying the cruise. The ODP started numbering the scientific cruises of the *JR* at Leg 101. A leg was nominally two months duration. During the 18+ years of the ODP, there were 110 cruises on the *JR*.	Integer 3
Site	Number identifying the site. A site is the location where one or more holes were drilled while the ship was positioned over a single acoustic beacon. The *JR* visited 656 unique sites during the course of the ODP. Some sites were visited multiple times, including some sites originally visited during the Deep Sea Drilling Program for a total of 673 site visits.	Integer 4
Hole	Letter identifying the hole. Multiple holes could be drilled at a single site by pulling the drill pipe above the seafloor, moving the ship some distance away and drilling another hole. The first hole was designated 'A' and additional holes proceeded alphabetically at a given site. Location information for the cruise was determined by hole latitude and longitude. During ODP, there were 1818 holes drilled or deepened.	Text 1
Core	Cores are numbered serially from the top of the hole downward. Cored intervals are up to 9.7 m long, the maximum length of the core barrel. Recovered material was placed at the top of the cored interval, even when recovery was less than 100%. More than 220 km of core were recovered by the ODP.	Integer 3
Type	All cores are tagged by a letter code that identifies the coring method used.	Text 1
Section	Cores are cut into 1.5 m sections in order to make them easier to handle. Sections are numbered serially, with Section 1 at the top of the core. GRA measurements were made on sections. Core Catcher sections identified as "CC".	Integer 2 (Text 2)
Top (cm)	The top interval of a measurement in centimeters measured from the top of a section.	Decimal F4.1
Depth (mbsf)	Distance in meters from the seafloor to the measurement location.	Decimal F7.3
Density (g/cm^3)	The calculated bulk density at an analysis interval. **Legs 169 Site 1037 -- 210:** Bulk density value is calculated using calibration information and number of counts. **Legs 101 -- 169, Site 1036:** Bulk density value is corrected for overestimation of water using calculation called 'Boyce correction.'	Decimal F7.3 Decimal F7.3
Run Number	Number generated by the data acquisition software, to identify an analysis run of a section of core.	Text 5
Run Date/Time	Timestamp when analysis was run.	Text 16 (yyyy-mm-dd hh:mi)
Core Status	Indicates whether a whole or half (split) core is being analyzed. Valid values are FULL or HALF.	Text 11
Liner Status	Records if a core liner was used, a split liner or no liner. Valid values are FULL, HALF and NONE.	Text 12
Requested Interval	Requested sampling interval (Legs 101 - 162 interval units in seconds; Legs 163 - 210 interval units in centimeters).	Decimal F5.3
Requested Period	Requested sampling period in seconds.	Decimal F7.3
Actual Period	Actual sampling period.	Decimal F7.3
Counts per Second	The measured counts collected by a shielded scintillation detector during a measurement.	Integer 10
Core Diameter	Diameter of the core in centimeters.	Decimal F5.2

Column Name	Column Description and Calculation	Format
Calib. Date/Time	Timestamp when calibration was run.	Text 16 (yyyy-mm-dd hh:mi)
Calib. Intercept	Density_M0 -- The intercept (m0) determined for a GRA calibration, in g/cm^3.	Decimal F8.4
Calib. Slope	Density_M1 -- The slope (m1) determined for a GRA calibration, in (g/cm^3)/counts.	Decimal F8.4